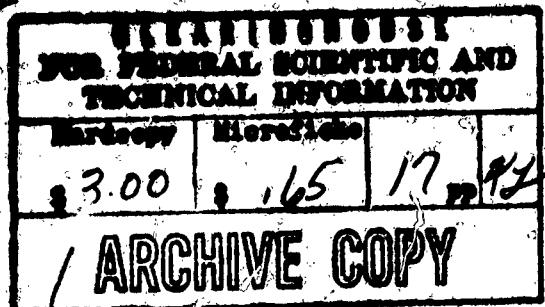


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F-4C FLIGHT SIMULATOR FLASHBLINDNESS EXPERIMENT

JAMES E. HAMILTON, Captain, USAF, BSC



August 1966

DEC 5 1966

**USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas**

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F-4C FLIGHT SIMULATOR FLASHBLINDNESS EXPERIMENT

JAMES E. HAMILTON, Captain, USAF, BSC

FOREWORD

This report was prepared in the Ophthalmology Branch. The experiment was accomplished at Davis-Monthan AFB, Ariz., during the month of August 1965. The work was in support of task No. 630103 and was funded by the Defense Atomic Support Agency under project No. 5710. The approved paper was received for publication on 6 June 1966.

The author gratefully acknowledges the technical and professional assistance of Richard C. McNee, Captain Kurt E. Bauermeister, Airman Second Class Peter C. Hesslink, and especially Everett O. Richey, whose assistance was most helpful.

Thanks are also offered to all the pilots of the 4453d Combat Crew Training Wing and the support personnel who maintain and operate the F-4C flight simulators at Davis-Monthan AFB for their cooperation in participating in the flashblindness experiment. Captain Theodore R. Kramer, an experienced F-4C pilot of the 4456th Combat Crew Training Squadron, Davis-Monthan AFB, determined the baseline of the F-4C aircraft simulator used in this experiment.

The operational maneuver performed in this experiment was specifically designed for this research and does not represent any known profiled escape maneuver following delivery of a nuclear weapon.

This report has been reviewed and is approved.

Harold V. Ellingson
HAROLD V. ELLINGSON
Colonel, MC, USAF
Commander

ABSTRACT

A study was made to determine visual recovery time from flashblindness in the F-4C aircraft simulator. When 1,080 lux (100 ft.-c.) panel illumination was used immediately after the pilot was exposed to a flash of light in the forward cockpit, visual recovery time was significantly reduced.

Visual recovery time was significantly less in the F-4C simulator than that found by previous studies in the F-106 and the C-131 simulators, even though the same light source and recovery task were used. The effect of flashblindness on aircraft control in the F-4C was similar to that found in the F-106 and the C-131 studies.

Even though recovery time is significantly shorter than that found in the F-106 simulator under the conditions of this test, there is evidence that flashblindness may still be a problem because of its effect on aircraft control in the F-4C aircraft simulator.

F-4C FLIGHT SIMULATOR FLASHBLINDNESS EXPERIMENT

I. INTRODUCTION

There is considerable evidence that flashblindness from nuclear detonations will be a problem for combat pilots during combat operations at night. The magnitude of this problem is still under investigation. Although many studies have been made over the last several years to provide eye protection from retinal burn and flashblindness under nighttime conditions (1), the problem remains unsolved.

Until some type of optical protection can be provided, some precautionary method must be supplied to aid the combat pilot in case he is subjected to a nuclear war.

Previous studies (2, 3), similar in nature to the present study, have indicated that recovery time from flashblindness can be reduced by more than 50% within the aircraft simulator cockpit by floodlighting the instrument panel immediately after exposure to a bright flash of light. The floodlighting may be gradually reduced after the initial activation to coincide with the dissipation of after image produced by the light. Excessive floodlighting time and intensity will only prolong recovery of valuable night vision.

The purpose of the present study is to determine the effect of flashblindness on aircraft control in the F-4C flight simulator. In addition, a study was made to determine the effect of increased instrument-panel illumination on flashblindness recovery time.

The subjects for the experiment were pilots assigned to the 4453d Combat Crew Training Wing, Davis-Monthan AFB, Ariz., who were undergoing training in the F-4C fighter aircraft.

The present study is a continuation of the F-101/F-106 flight simulator flashblindness experiment by the author (2) and the C-131A/T-29 flight simulator flashblindness study by Alder (3). The instrumentation and procedure for this experiment were the same as those used in the F-101/F-106 experiment.

II. APPARATUS AND PROCEDURE

Two F-4C (fig. 1) aircraft flight simulators at Davis-Monthan AFB, Ariz., were utilized for the flashblindness experiment. One portable, fly-away, visual flash-source kit (figs. 2 and 3), designed by the author and built at the USAF School of Aerospace Medicine, was attached to each aircraft simulator. Each of the kits contained the following items: Honeywell Strobonar, model 65-C electronic flash lamp; Sylvania time clock and sun lamp rheostat;



FIGURE 1
F-4C aircraft flight simulator.

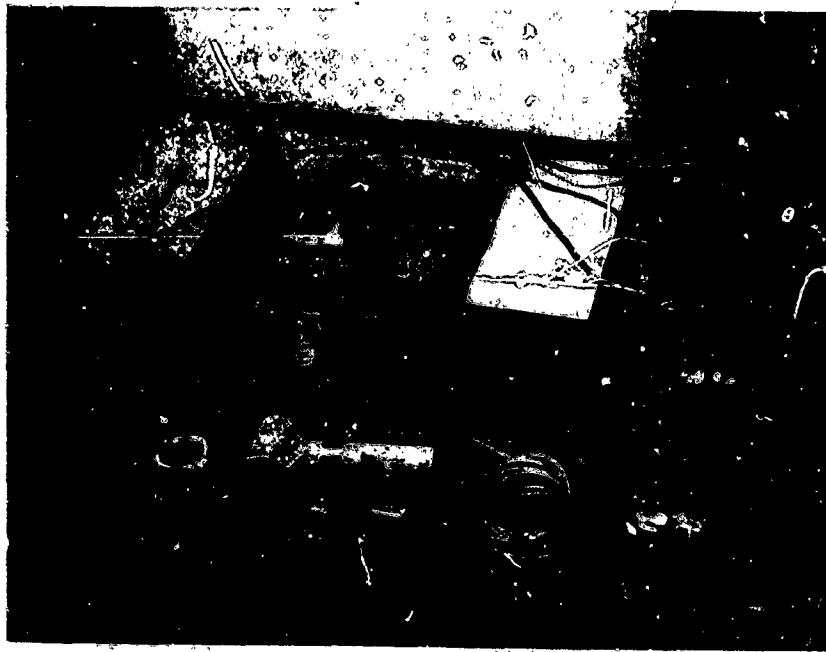


FIGURE 2
Diagram of visual flash-source instrumentation.



FIGURE 3
Visual flash-source kit and F-4C flight simulator.

Kodak Instamatic camera and triggering solenoid; Weston illuminometer; console panel with switches, lights, and wiring; Snellen distance test chart; ocular occluder; instrument-connecting cables with proper plugs and sockets; package of assorted attachment brackets; two Sylvania sun lamps; and 10 rolls of Kodak 35 mm. Kodachrome film.

Flight and weapons control for each simulator could be monitored and the visual flash-source equipment could be controlled by the investigator from separate control panels outside each cockpit (figs. 4 and 5). Component parts of each flash-source kit were constructed to be quickly attached to specific areas of the aircraft simulator and controlled from the console panel within the portable case (fig. 2). The size of the case is 0.42 by 0.27 by 0.76 m. (16½ by 10½ by 30 in.).

The visual flash-source system was electronically constructed so that when the pilot

simulated firing of a special weapon, the electronic flash lamp¹ positioned above the control panel (No. 1 in fig. 6) was triggered to produce the light flash. The electronic flash lamp was positioned at a distance² from the eyes of the pilot of 0.72 m. (28.5 in.) in one F-4C simulator and 0.76 m. (30 in.) in the other F-4C simulator. A time-delay switch allowed the proper time to elapse between the weapon release and

¹The measured radiant energy output per flash is 4.8×10^4 nit. seconds (candle-sec./m.²).

²The light subtended about a 4-degree angle at the eye.



FIGURE 4

Monitoring station for F-4C aircraft flight simulator.

the light flash. At the time of the electronic lamp flash, a sun lamp³ (fig. 2) also flashed with a pulse duration of 1 second. This lamp was positioned under the front canopy, but faced upward to reflect light from the inner surface of the canopy, which was covered with white material to produce a highly reflecting inside surface. It simulated light produced by reflection from clouds and other gaseous particles comprising the denser atmosphere near the surface of the earth. The pulse duration and intensity of the electronic flash lamp were not equal to the pulse duration and intensity of the special weapon which would be fired from the actual aircraft, but did produce a significant amount of flashblindness whenever the subject viewed the lamp directly. It will not produce a retinal burn (4). The simultaneous flashing of these two lamps in the forward cockpit produced a double-pulse flash.

At the time both lamps in the forward cockpit were flashed, a camera (No. 2 in fig. 6) photographed the subject. The camera was mounted on top of the instrument panel at a distance of 0.71 m. (28 in.) to 0.79 m. (31 in.) from the pilot's eyes. From each picture, it could be determined if the subject had his eyes open and was looking directly into the electronic flash lamp when the flash occurred. If he blinked or was not looking directly at the lamp, data obtained on this exposure were

³The center-beam candlepower was 6.5×10^3 on HI position.

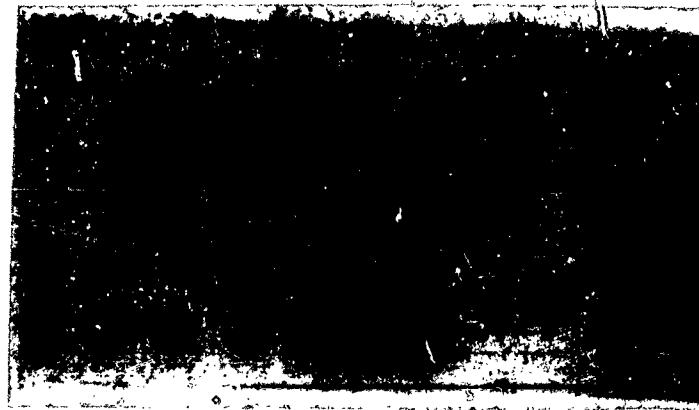


FIGURE 5

Instruments for F-4C simulator monitoring station.

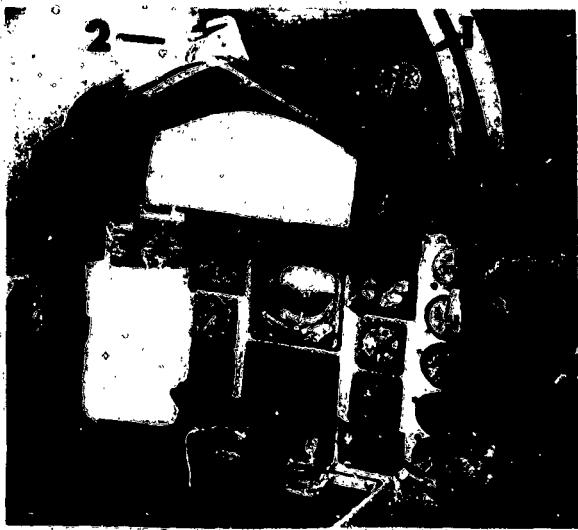


FIGURE 6

Forward canopy and instrument panel of the F-4C simulator showing strobe electronic flash lamp, 1; camera, 2; and gyrocompass, 3.

disregarded. The camera operated automatically, since it contained a spring-winding automatic film transport and was attached to an electric motor which released the shutter mechanism when the lights were pulsed.

The time clock on the control panel of the visual flash-source kit was automatically activated at the time the two forward lamps and the camera were activated (fig. 2). The clock could be manually stopped at the control panel by the investigator whenever the pilot recovered sufficiently from flashblindness to read the aircraft instrument panel and to report over the intercommunication system.

A second sun lamp of variable intensity was mounted on the right side of the pilot (No. 4 in fig. 7) at a distance of 0.91 m. (36 in.) from the gyrocompass and facing it. The instrument-panel gyrocompass was located at a distance of 0.76 m. (30 in.) to 0.79 m. (31 in.) from the pilot's eyes. This lamp could be activated and have its intensity controlled at will by the investigator at the kit control panel outside the cockpit. The system was wired so the lamp could be activated simultaneously with the two forward lamps, the camera, and the time clock,

when desired. The purpose of this lamp was to flood the instrument panel with light. An illuminance of zero lux to well above 6,480 lux (lumen/m.²) (600 ft.-c.) could be produced at the instrument panel. The maximum illumination which can be produced on the instrument panel by the pilots is 2.16 lux (0.2 ft.-c.) for each aircraft simulator. Extra lighting could be produced by the pilot's turning on the thunderstorm lights, but these lights were not used for this experiment.

A switch was located in the visual flash-source kit which would activate only the forward sun lamp to simulate diffuse light produced by a flash somewhere to the rear of the aircraft. A flash from this lamp produced no significant amount of flashblindness, nor did it have any significant effect on aircraft control.

Lights on the control panel of the visual flash-source kit indicated when a.c. and d.c. power was applied to the kit, when the simulated special weapon was released, and when the flash occurred.

After each firing of the weapon system by the subject, the flash-source kit was reset for another firing by a reset button on the kit

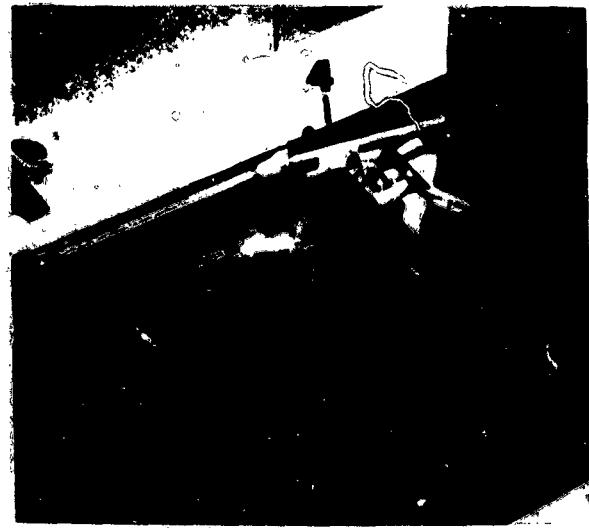


FIGURE 7
Instrument-panel flood lamp (4) in the F-4C.

console panel. If the time clock was used, it was also reset manually. The kit was wired to the special weapons release system of the aircraft simulator, the 28-v. d.c. power system of the aircraft simulator, the 110-v. a.c. power system located outside the simulator, and to the items inside the aircraft simulator which were controlled from the visual flash-source kit.

The pattern which the pilot was required to fly during the test escape maneuver (baseline) was determined. The baseline was accomplished without the use of a simulated light flash or an increased panel illumination. The pilot prepared his approach to the target by climbing to and leveling off at 7.5 km. (25,000 ft.), maintaining a heading of 360 degrees and a true airspeed of 991 km. hr. (535 knots). The instrument panel was illuminated by 2.16 lux (0.2 ft.-c.) of light. The pilot initiated a 45-degree bank to the left and maximum climb, without using afterburners, 5 seconds after the weapon was manually released. This attitude was to be maintained until the simulator was frozen in-flight or the aircraft reached a heading of 180 degrees, whichever occurred first.

At intervals of 5 seconds from 0 to 30 seconds, the simulator was frozen in-flight and the aircraft attitude was recorded. Each time the simulator was unfrozen, the target approach was initiated from the beginning over the same course. The baseline data are shown in figures 10 to 15. Because of time limitations, only one finding was made at each 5-second interval during the determination of the baseline.

Before the simulator flashblindness study, each pilot was briefed individually concerning the nature of the experiment. He was also given an explanation of flashblindness and instructions concerning the escape maneuver to be used for the experiment. The pilot's decision to participate in the program was strictly voluntary. Each one was given a distance visual acuity test for each eye separately on a Snellen test chart before and after the experiment.

The aircraft simulator was made ready for use and armed, and the lighting inside the

canopy was turned down to an intensity that would normally be used on a night flight. Only 2.16 lux (0.2 ft.-c.) of illumination was produced on the instrument panel and consoles of the aircraft. The pilot could communicate with the investigator and the operator of the aircraft simulator control system.

The pilot entered the aircraft simulator, closed the canopy, and flew to an altitude of 7.5 km. (25,000 ft.). At an approximate true airspeed of 991 km. hr. (535 knots) and on a different heading each time, he approached a target and locked on the target by radar. At the proper time, a simulated special weapon was released manually by the pilot at the target which was being tracked on the aircraft radar screen. The aircraft was held on a straight course toward the target until a light flash occurred. The pilot then attempted to place the aircraft into a 45-degree bank to the left and maximum climb toward a new heading of 180 degrees from the original heading. Afterburners were not to be used.

Immediately after the simulated weapon release, the pilot was asked by the investigator to look directly at the electronic flash lamp above the instrument panel. When the lamp was flashed, the pilot was temporarily flash-blinded (fig. 8). Immediately after the flash, while the pilot was attempting to perform the escape maneuver, he was asked to report his gyrocompass heading to the investigator as soon as he was reasonably sure of his heading. The aircraft instruments were monitored outside the aircraft. As soon as a correct reading was reported, the time clock was manually stopped by the investigator and all aircraft instruments were frozen. Data were now recorded from the aircraft's gyrocompass, airspeed indicator, altimeter, climb-rate indicator, attitude indicator, and the angle-of-attack indicator. In addition, flashblindness recovery time was recorded from the time clock of the visual flash-source kit.

Each subject generally made from 4 to 7 passes at the target, but was exposed to the light flash during only 3 of these passes. He did not know on which pass the flash would



FIGURE 8

Pilot viewing light at the time of flash.

occur. When it did not occur, he maintained his original heading and prepared for another lock-on on another target. After the first flash, the instrument panel was not illuminated by the instrument-panel flood lamp (only the standard illumination 2.16 lux (0.2 ft.-c.) was used). For the second flash, 1,080 lux (100 ft.-c.) of illumination was used; and for the third, 3,240 lux (300 ft.-c.) of illumination lighted the instruments immediately following the flash. The panel illumination was always produced in this order for each pilot. This is different from the F-106 study in which panel illumination following the flash occurred in no specific order (2). This procedure was used in both F-4C aircraft simulators.

III. RESULTS AND CONCLUSIONS

Twenty-one pilots volunteered to be subjects for the flashblindness experiment in the F-4C aircraft simulators. All were lieutenants

who were assigned to the 4453d Combat Crew Training Wing for training in the F-4C aircraft. Since these subjects were trainees in the simulator, some variations may be attributed to their inexperience. None was required to wear lenses while flying. Unaided visual acuity was 6/6 (20/20) plus or minus 2 or 3 Snellen letters. The flashblindness experiment did not affect the visual acuity of any subject.

The means, standard deviations, and sample sizes are given in table I for recovery times determined during the F-4C simulator experiment, for data obtained by Hamilton (2) on the F-106 simulator experiment, and for data obtained by Alder (3) on the C-131 simulator study. The standard deviations shown are not correct for comparing panel illuminations, but can be used for comparing simulators. The F-4C mean was significantly lower than the F-106 and the C-131 means at 1,080 lux (100 ft.-c.) illumination ($P < .01$), but no other differences were detected between simulators.

Figure 9 shows mean recovery time under three conditions of instrument-panel flood-lighting for the F-4C, F-106, and the C-131 simulator studies. Recovery time for the C-131 simulator (3) was considered only for the case where reading the gyrocompass was the visual task used. This was the only instrument utilized in the measurement of recovery time in the F-4C and the F-106 simulators.

The recovery times for illuminations for the F-4C simulator were compared in pairs (table I), since the variability is much larger when 2.16 lux illumination is one of the illuminations being compared and also the maximum number of pilots can be used in each comparison. The recovery times for the 2.16 lux and 1,080 lux panel illuminations were significantly different ($P < .05$).

Table II gives the summary statistics for the measurements of position and attitude of the aircraft recorded at the time of recovery from flashblindness. A minus sign indicates a negative angle of attack, deceleration, loss of altitude, or a negative rate of climb.

TABLE I

Means and standard deviations* for recovery time (seconds) for each panel illumination for each flight

Flight	2.16 lux (0.2 ft.-c.)			1,080 lux (100 ft.-c.)			3,240 lux (300 ft.-c.)		
	N	\bar{X}	S.D.	N	\bar{X}	S.D.	N	\bar{X}	S.D.
F-4C	13	20.71	15.65	14	7.42	2.25	15	10.63	9.66
F-106	8	27.96	12.00	7	12.18	3.84	8	10.44	4.56
C-131	32	26.82	6.66	32	10.68	3.24	32	10.74	4.02

The F-101 data are not included in the comparison of data with the present experiment because of the small amount collected.

*These standard deviations are not correct for comparing panel illuminations.

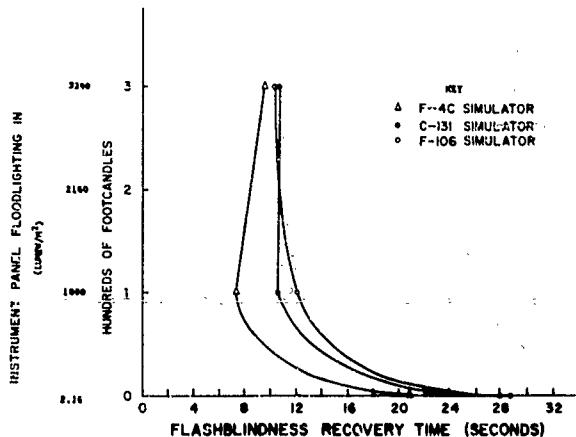


FIGURE 9

Flashblindness recovery time in seconds.

The change from the original heading is not a good criterion for directional control of the aircraft because of the mean rapid recovery time in the F-4C simulator.

Some subjective tolerances were obtained from experienced pilots for the maneuver which was flown during the period of flashblindness. These limits must be extended, however, owing to uncontrolled variables present in the experiment.

It was discovered during the procedure of determining the baseline that a 45-degree bank maximum climb to the left produced a mean turn-rate of 2.0 degrees per second for the first

15 seconds and gradually increased to as much as 2.8 degrees per second during the succeeding 10 seconds (ABC, fig. 10). A recommended tolerance of ± 10 degrees was arbitrarily changed so that only those cases which lagged more than 15 degrees behind the baseline turn-rate were failed. Since the G-force is not experienced or controlled in this experiment, during the bank a large tolerance from the mean heading during the period of flashblindness is required. Seven out of 42 passes (17%) were outside the designated allowable controlled limits at recovery time. There is evidence that some of the pilots may have underbanked in the beginning of their flashblindness period and overbanked to get within the safety zone before recovery. For this reason, a large negative tolerance was allowed.

Position of the aircraft at recovery time is noted by symbols in figures 10 through 15. A closed circle indicates 2.16 lux (0.2 ft.-c.) panel illumination; an open circle indicates 1,080 lux (100 ft.-c.) panel illumination; an open triangle indicates 3,240 lux (300 ft.-c.) panel illumination; and a closed triangle indicates the baseline at 2.16 lux. There is no correlation between any panel illumination levels and the position of the aircraft at recovery time within the safety zone.

A study of the angle of bank (fig. 11) at recovery time showed no relation to the heading of the aircraft (fig. 10) at the time of recovery. The degree of bank could be varied

TABLE II
Summary of measurements at end of flashblindness period

Measurement	Illumination (lux)	N	Min.	Max.	\bar{X}
Heading difference (degrees/min.)	2.16	11	1	159	44.2
	1,080	12	0	40	19.9
	3,240	12	7	67	24.7
Angle of attack (degrees)	2.16	13	6	21	9.9
	1,080	14	-15	13	6.6
	3,240	15	0	20	9.7
Airspeed difference (km./hr.)	2.16	10	-460	139	-81
	1,080	12	-506	74	-48
	3,240	12	-52	98	6.5
Altitude difference (km.)	2.16	10	0.0	2.3	0.82
	1,080	12	-0.21	0.64	0.19
	3,240	12	-0.67	2.13	0.42
Climb rate (meters/sec.)	2.16	13	91	1829+	1374
	1,080	14	-914	1829+	995
	3,240	15	-914	1829+	1267
Bank (degrees)	2.16	6	10	70	37.5
	1,080	9	15	60	41.7
	3,240	10	10	60	41.0

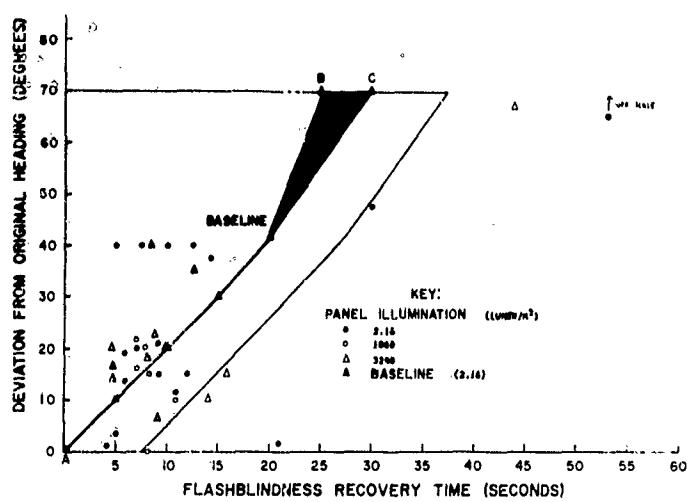


FIGURE 10
Heading raw data.

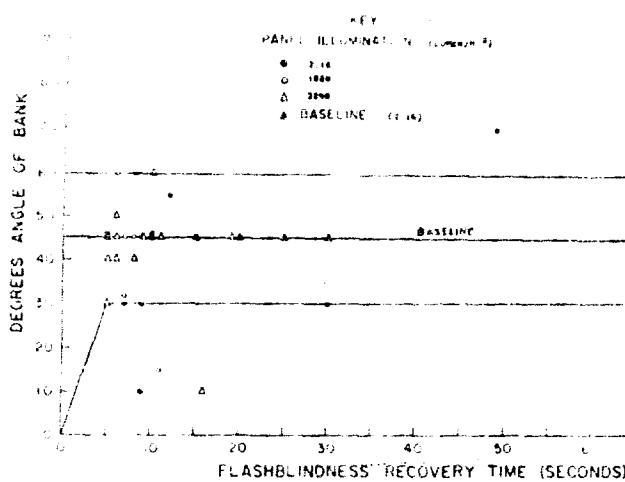


FIGURE 11
Bank raw data.

during flashblindness recovery time. It is unknown why six pilots banked to the right after weapon release instead of to the left. They were not failed.

Figure 11 indicates that in 4 out of 42 passes (10%), the pilots had their simulator banked more than 60 degrees or less than 30 degrees at the time of recovery. This allowed 15 degrees in either direction from the prescribed 45-degree bank during the escape maneuver. Experienced pilots recommended tolerances ranging from ± 3 to ± 15 degrees. The most liberal has been chosen. While the baseline of the simulator was being established, a 45-degree bank was attained in less than 5 seconds and was maintained after that time.

During the time that a baseline was being established, an approximate altitude gain of 76.2 m./sec. (250 ft./sec.) was attained during the first 30 seconds of the maneuver (fig. 12). Owing to the lack of controlled variables in the experiment, the recommended tolerance of ± 15.24 m./sec. (50 ft./sec.) has been extended to fail only those subjects who lost altitude or failed to show any altitude gain at recovery time. Five pilots who lost altitude and one who had no altitude gain at recovery time (14%) were considered to have failed the test. Two

pilots who encountered a loss of altitude were not failed because of a simulator mechanical problem (labeled SP, fig. 12).

Four pilots who had lost altitude at recovery time also had a negative climb rate (10%) at that time (fig. 13). The climb-rate indicator registered a maximum of 1,829 m. min. (6,000 ft./min.). The maximum rate was attained within 10 seconds while the baseline was being established. Even though a ± 5 -second tolerance was recommended to attain the maximum climb rate, only subjects who had a negative climb at recovery time were considered as failures.

While the baseline was being ascertained, the angle of attack increased progressively to ± 7 in the first 15 seconds and then progressed less and less rapidly to ± 13 at the end of 30 seconds (fig. 14). The students generally had a higher angle of attack than that prescribed in the baseline. This is expected since the students maintained a greater rate of climb than that prescribed in the baseline. Two pilots (5%) had a negative angle of attack at recovery time. They were the only ones considered as failing this test even though a ± 15 -second tolerance was recommended along the flight path.

Figure 15 indicates that true airspeed dropped from 991 km./hr. (535 knots) to 408 km./hr. (220 knots) during the first 30 seconds of the prescribed escape maneuver. Again, the students maintained a true airspeed very near their original airspeed. This fact and the fact that they maintained a higher angle of attack than that of the baseline pilot is evidence that they may have been using afterburners to outmaneuver him. At any rate, this cannot be counted against them even though a pilot may have failed a pass if he had not used his afterburner. Loss (or no gain) of altitude, a significant deviation from the prescribed heading, or a significant amount of overbank or underbank could be considered as a basis for failing a pass. No one was failed by the airspeed test alone even though a speed of ± 10 knots would be recommended under controlled conditions. Climb rate and attack angle were also failing factors.

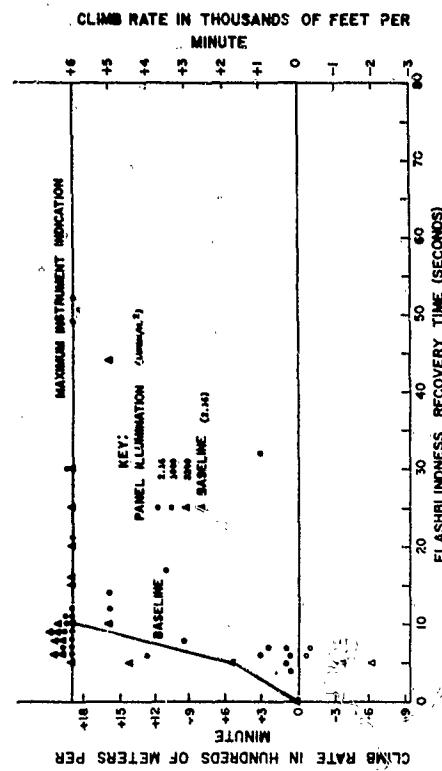


FIGURE 12
Altitude raw data.

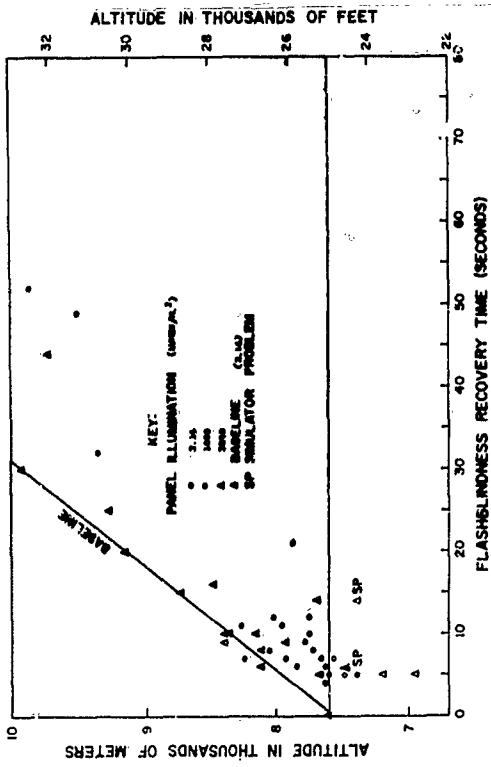


FIGURE 13
Climb rate raw data.

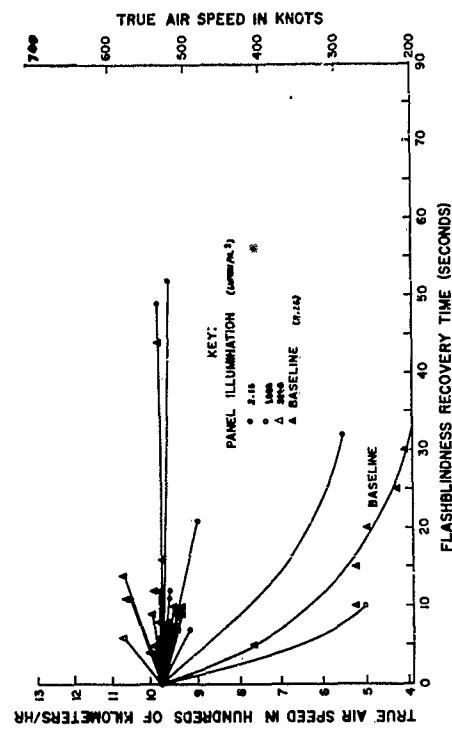


FIGURE 14
Angle of attack raw data.

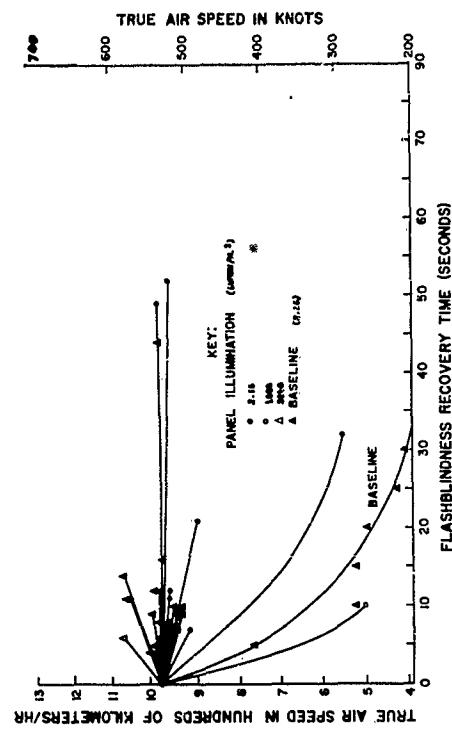


FIGURE 15
True airspeed raw data.

Each pilot was carefully instructed to release his weapon at 7.5 km. (25,000 ft.) above sea level while moving at approximately 991 km./hr. (535 knots true airspeed) on an arbitrary compass heading. Of the total 42 passes, 17 (40%) were failed because the aircraft simulator was not in the intended attitude and position at recovery time. At least one of the following aircraft attitudes was present at this time: (1) lag of more than 15 degrees from the baseline course; (2) deviation of more than 15 degrees from a 45-degree bank; (3) loss or no gain in altitude; (4) zero or negative climb rate; and (5) negative angle of attack.

Flashblindness recovery time in the F-4C aircraft simulator was significantly less than the mean recovery time in the F-106 and the C-131 simulators under the conditions of the experiment. Control of the aircraft was significantly affected by flashblindness in 40% of the flights in the F-4C aircraft simulators.

Recovery time was significantly reduced by floodlighting the cockpit with 1,080 lux of illu-

mination immediately following the flash. The increase of floodlighting to 3,240 lux did not significantly change recovery time. This agrees with the previous findings in the F-106 and the C-131 studies.

IV. RECOMMENDATION

As a result of the findings in this study it is again recommended, as in other previous studies in flashblindness performed at the USAF School of Aerospace Medicine, that all operational aircraft within the U. S. Air Force be outfitted with thunderstorm lights that will produce 1,350 lux (125 ft.-c.) of instrument-panel floodlighting. Such cockpit lighting will reduce flashblindness recovery time significantly in case the pilot is exposed to nuclear explosions or lightning flashes. In addition, such lighting will provide better visual discrimination of the aircraft instrument panel when the aircraft is flown over snow or in the direction of the sun during early morning or late afternoon hours (2).

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY USAF School of Aerospace Medicine Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas
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13. ABSTRACT

A study was made to determine visual recovery time from flashblindness in the F-4C aircraft simulator. When 1,080 lux (100 ft.-c.) panel illumination was used immediately after the pilot was exposed to a flash of light in the forward cockpit visual recovery time was significantly reduced.

Visual recovery time was significantly less in the F-4C simulator than that found by previous studies in the F-106 and the C-131 simulators, even though the same light source and recovery task were used. The effect of flashblindness on aircraft control in the F-4C was similar to that found in the F-106 and the C-131 studies.

Even though recovery time is significantly shorter than that found in the F-106 simulator under the conditions of this test, there is evidence that flashblindness may still be a problem because of its effect on aircraft control in the F-4C aircraft simulator.